



CLEAN WATER AND RENEWABLES

Village Power 2000

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<http://www.nmsu.edu/~tdi>

Clean Water Supply



- **Requirements for Successful RE Development**
- **PV Water Pumping**
- **Water Purification**
 - **Aeration**
 - **Boiling**
 - **Chlorination**
 - **Filters (carbon, sand, resin)**
 - **Deionization**
 - **Ultraviolet**
 - **Reverse Osmosis**
 - **Ozonation**
 - **Mixed Oxidants**
 - **Distillation**
- **Economic Comparison**
- **Effectiveness Comparison**

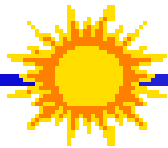


PV Water Pumping

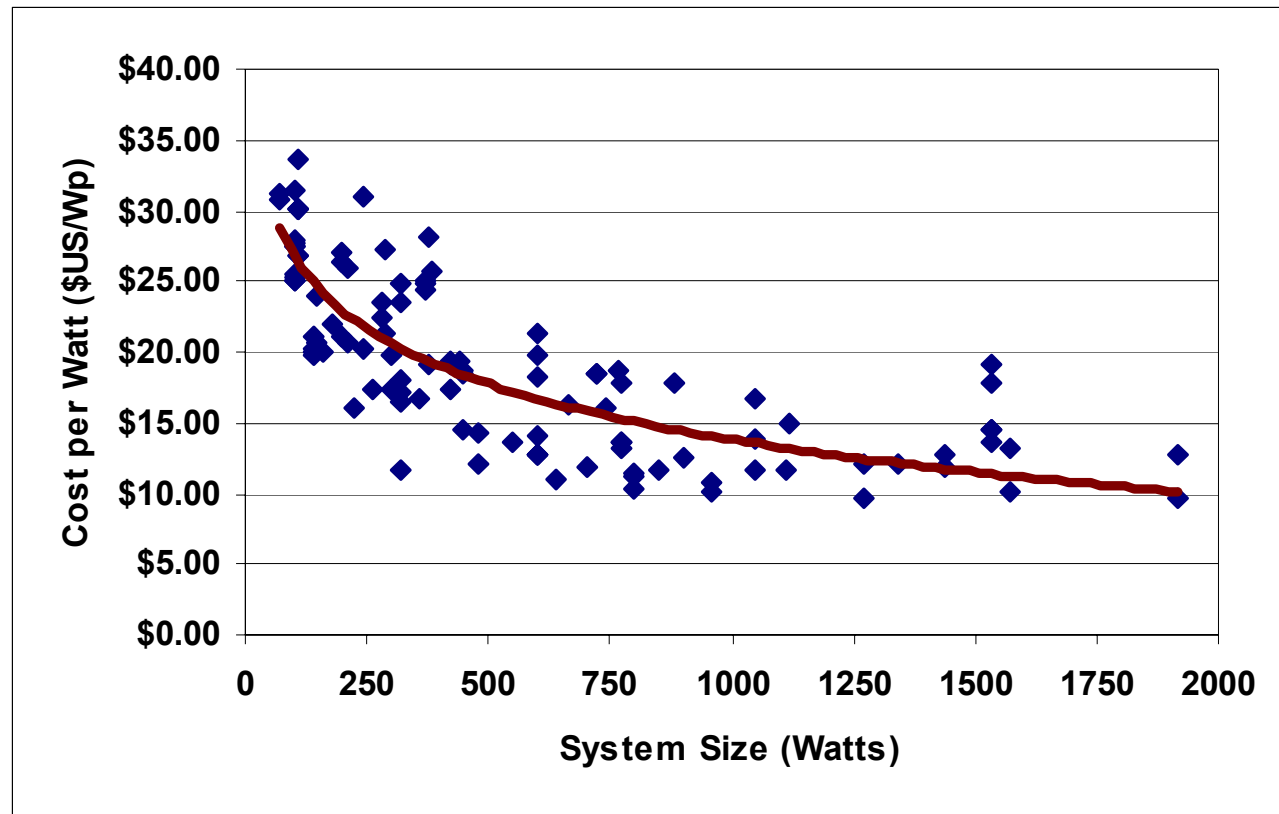
- Select most appropriate option (e.g, gravity feed, manual pumps)
- PV WP Applications
 - Domestic water supply
 - Livestock water supply
 - Small scale Irrigation



PV Water Pumping

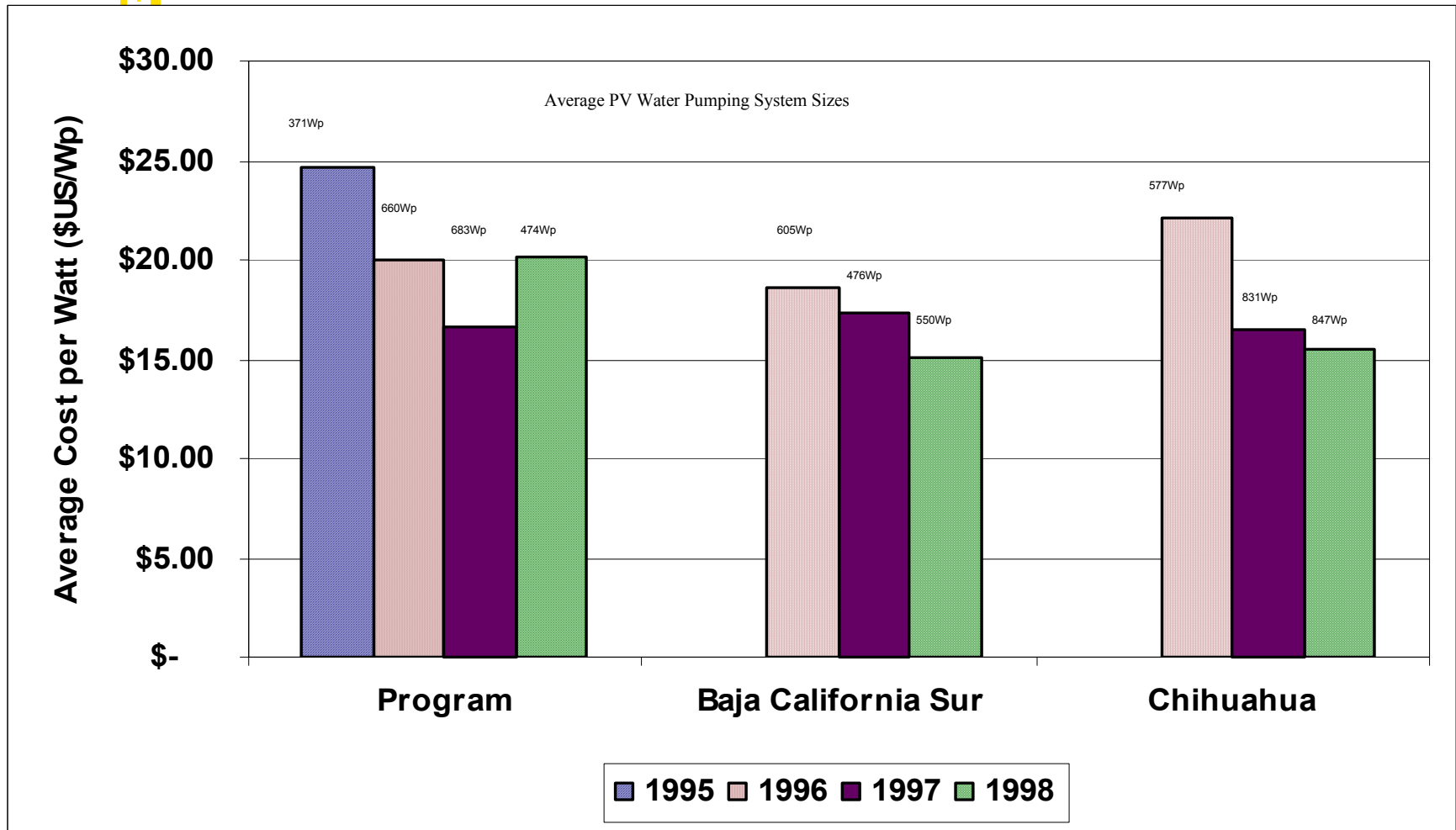
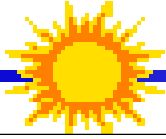


Mexico: Cost per Watt Vs. System Size



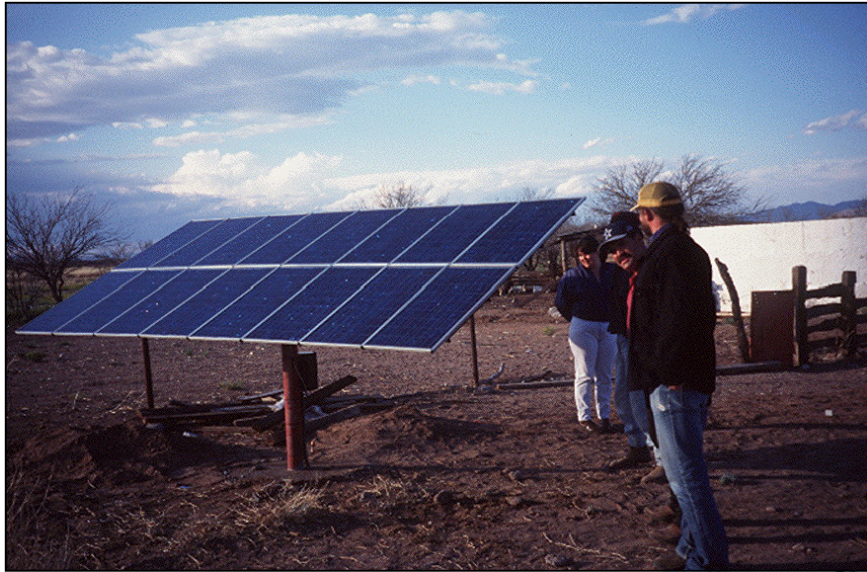
PV Water Pumpers for remote non-electrified sites are in general competitive when under 2 kW in size

Mexico program database shows that prices decrease as markets mature



Life-Cycle Cost Analysis

Case Study-El Jeromín, Chihuahua



AFTER

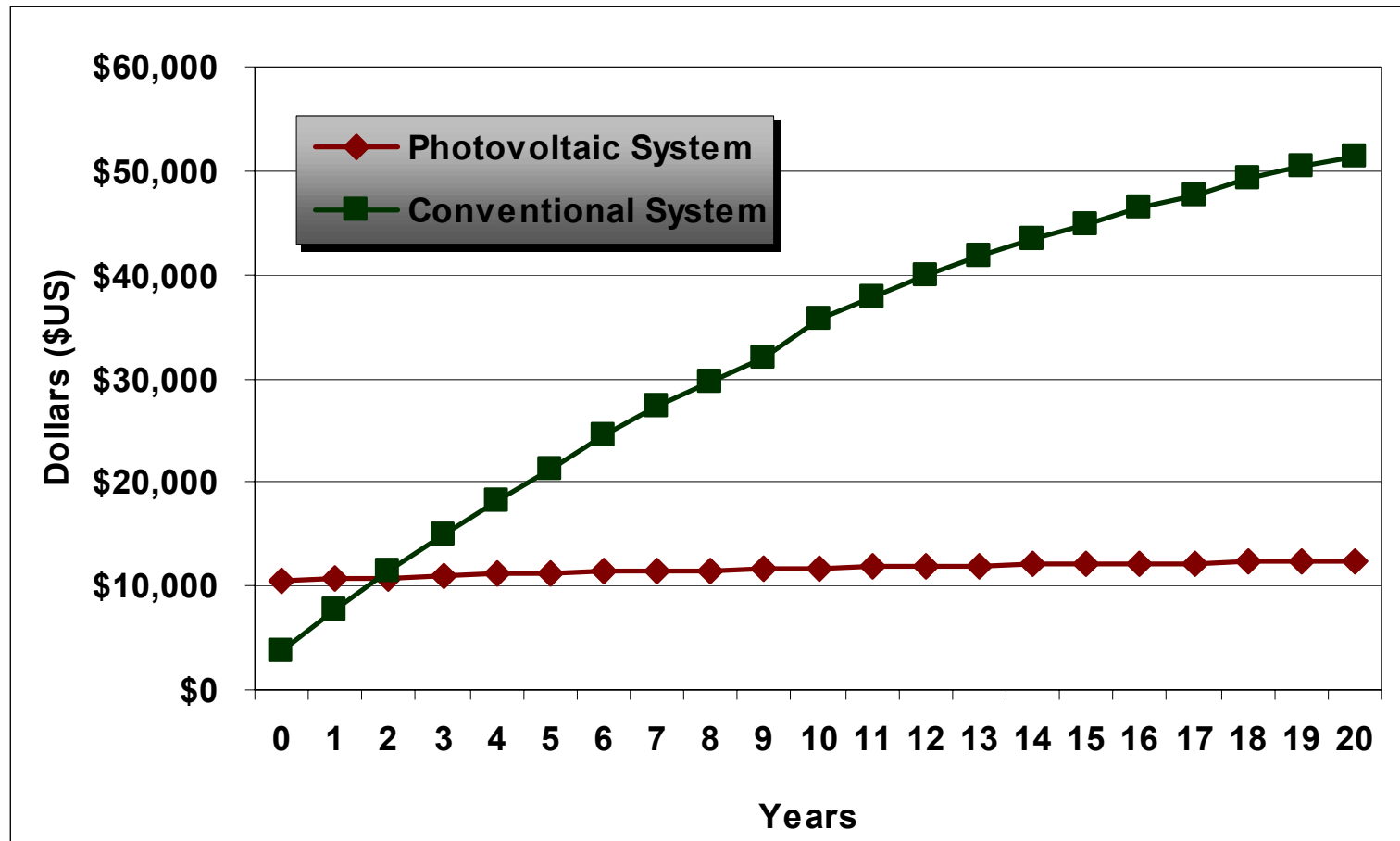


BEFORE

- 848 Wp PV system installed in March 1997 with no maintenance since
 - 16 Solarex VRX-53 modules
 - Grundfos SP3A-10 pump
 - SA-1500 controller
- Cattle Ranch with desert vegetation
- 15,000 liters of water per day

Case Study - El Jeromín, Chihuahua

Results



- After 2.5 years, the PV system represents a lower overall expense to the user

Life-Cycle Cost Analysis

Case Study-Agua Blanca, BCS

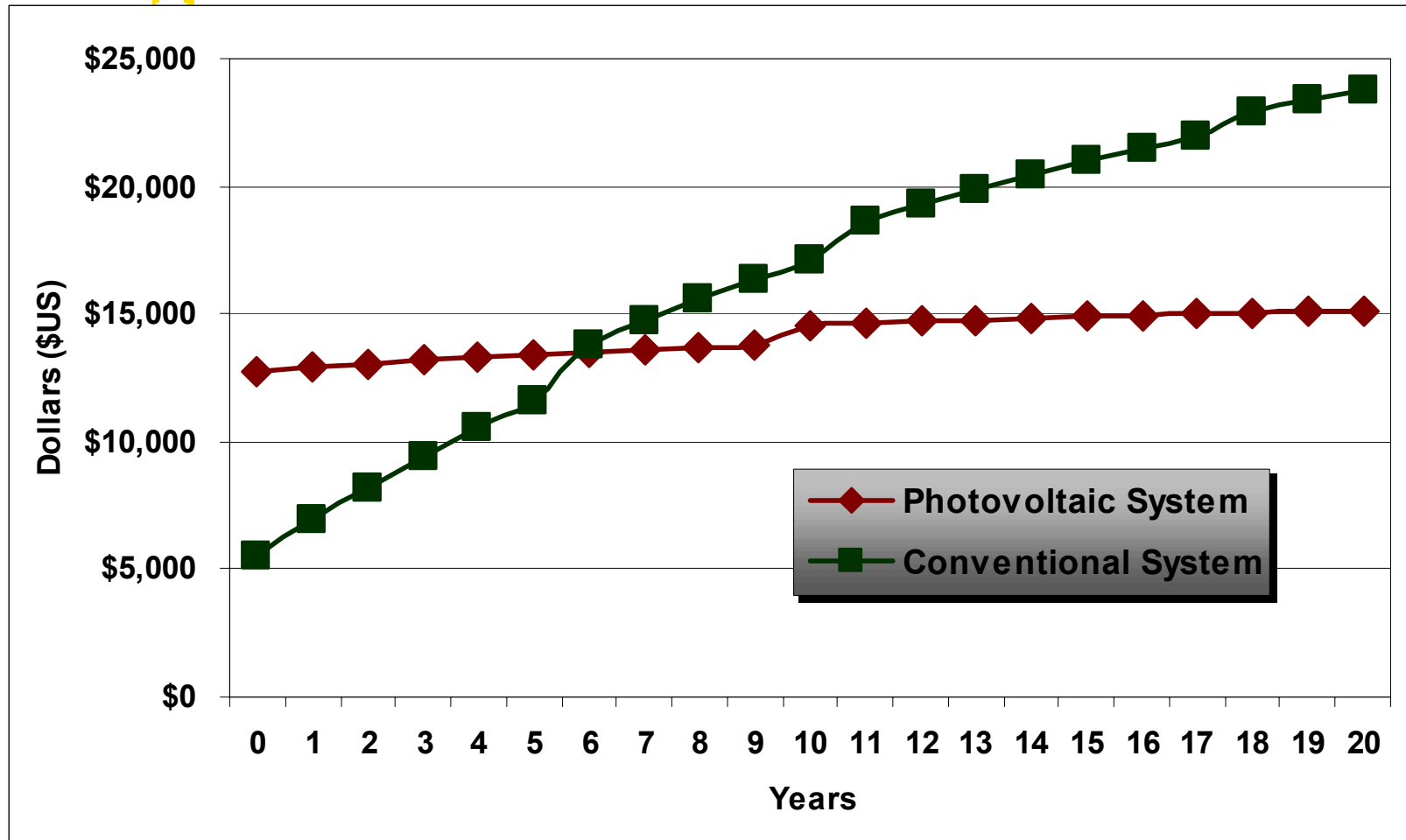
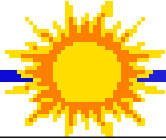


- **800 Wp PV system installed - March 1998**
 - 10 Kyocera KC-80 modules
 - SolarJack SCS-14-160 pump and controller
- **Livestock/irrigation ranch - 1,001 hectares**
- **Requirement 25,000 liters per day**



Case Study - Agua Blanca, BCS

Results



- Six years after installation, the PV system represents a lower overall expense to the owner



Aeration

- **Diffuse air into the water to oxidize metals such as manganese and iron**
- **Oxidize wastewater to reduce Biological Oxygen Demand (BOD)**
- **Pros**
 - **Simple and effective at removing some metals**
- **Cons**
 - **Does not disinfect or purify water otherwise**



Boiling

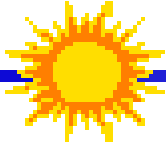
- **Boil water to kill harmful microbiological contaminants**
- **Pros**
 - Simple and effective in eliminating micro-organisms (bacteria and parasites)
- **Cons**
 - High energy inputs for small volume
 - No residual disinfection
 - Does not eliminate salts and minerals



Chlorination

- **Uses chlorine species to kill micro-organisms**
- **Pros**
 - **Effective disinfection**
 - **Provides residual disinfection**
- **Cons**
 - **No salt and mineral removal**
 - **Chlorination byproducts (THMs)**
 - **Requires chemical supply**

Filters



- **Sand Filter**
 - Removes suspended solids
 - No disinfection or dissolved solids removal
- **Carbon Filter**
 - Removes organic contaminants (gasoline, MTBE, pesticides)
 - No disinfection or dissolved solids removal
- **Resin Filter (softener)**
 - Removes calcium, magnesium, iron
 - No disinfection or dissolved solids removal



Deionization

- **Removes charged ions from the water using anionic and cationic resin.**
 - **First step cationic removal**
 - **Second step anionic removal**
- **Pros**
 - **Produces high quality water**
 - **Removes salts and minerals**
- **Cons**
 - **No disinfection**
 - **No residual**
 - **Resin regeneration chemicals required (NaCl or NaOH)**



Reverse Osmosis

- **Uses osmotic pressure to remove impurities**
- **Pros**
 - **Produces high quality water**
 - **Removes salts and minerals**
 - **Removes micro-organisms**
- **Cons**
 - **High energy inputs**
 - **High maintenance (membrane replacements)**
 - **No residual**

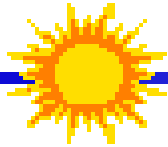


UV

- Uses ultraviolet light to disinfect water
- Pros
 - Eliminates micro-organisms without chemical addition
- Cons
 - No residual
 - No salts and minerals removed
 - Should replace UV bulb every year
 - Less effective in the presence of suspended solids



Solar UV





Ozonation

- **Uses electricity and air to create ozone for disinfection**
- **Pros**
 - **Strong disinfection capability**
- **Cons**
 - **No salt or minerals removed**
 - **No residual**
 - **High energy inputs**



Mixed Oxidants

- **Mixed oxidants is a combination of**
 - Ozone
 - Chlorine dioxide
 - Chlorine
- **Electrodialysis of NaCl to produce oxidants**
- **Pros**
 - Strong disinfecting solution
 - Provides residual disinfection capacity
- **Cons**
 - Does not remove dissolved minerals
 - Significant operator interface required
 - High energy inputs
 - Requires pure salt to operate



Solar Mixed Oxidants

Brine Mix

San Elizario, Texas

Injection Nozzle



MO Solution



MIOX Unit

25,000 gpd capacity

Distillation

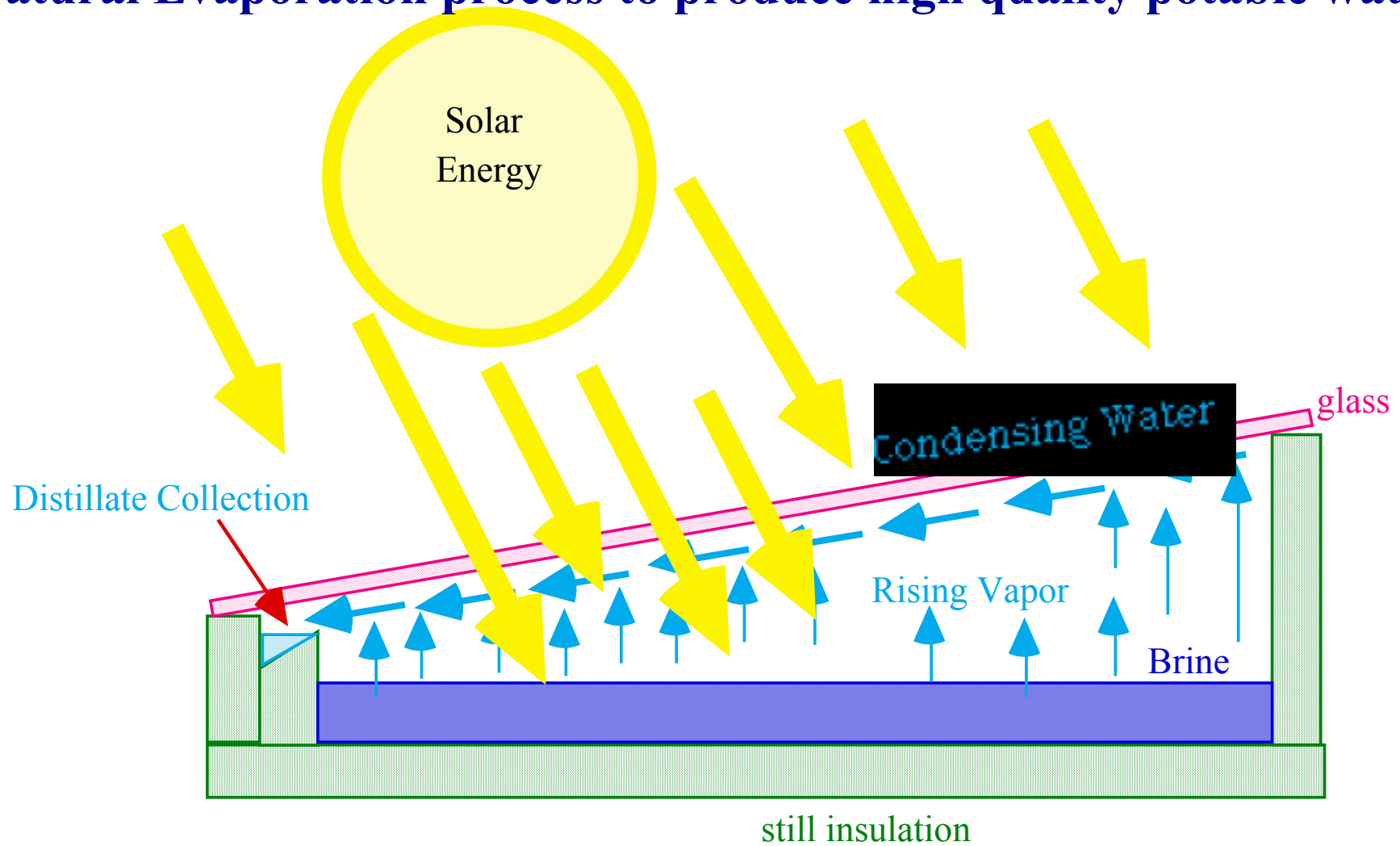


- **Distillation is effective in removing**
 - Salts/Minerals (e.g., Na, Ca, As, Fl, Fe, Mn)
 - Bacteria (e.g., E. Coli, Cholera, Botulinus)
 - Parasites (e.g., Giardia, Cryptosporidium)
 - Heavy Metals (e.g., Pb, Cd, Hg)
- **Pros**
 - High Water Quality
 - Solar Energy Easily Used
 - No Moving Parts
 - Long Life
 - Simple to Operate
 - Simple to Maintain
 - Low Life Cycle Cost
 - Can be Automated
- **Cons**
 - Small Product Volume
 - Potential VOC Carryover if no carbon filter used
 - No Residual

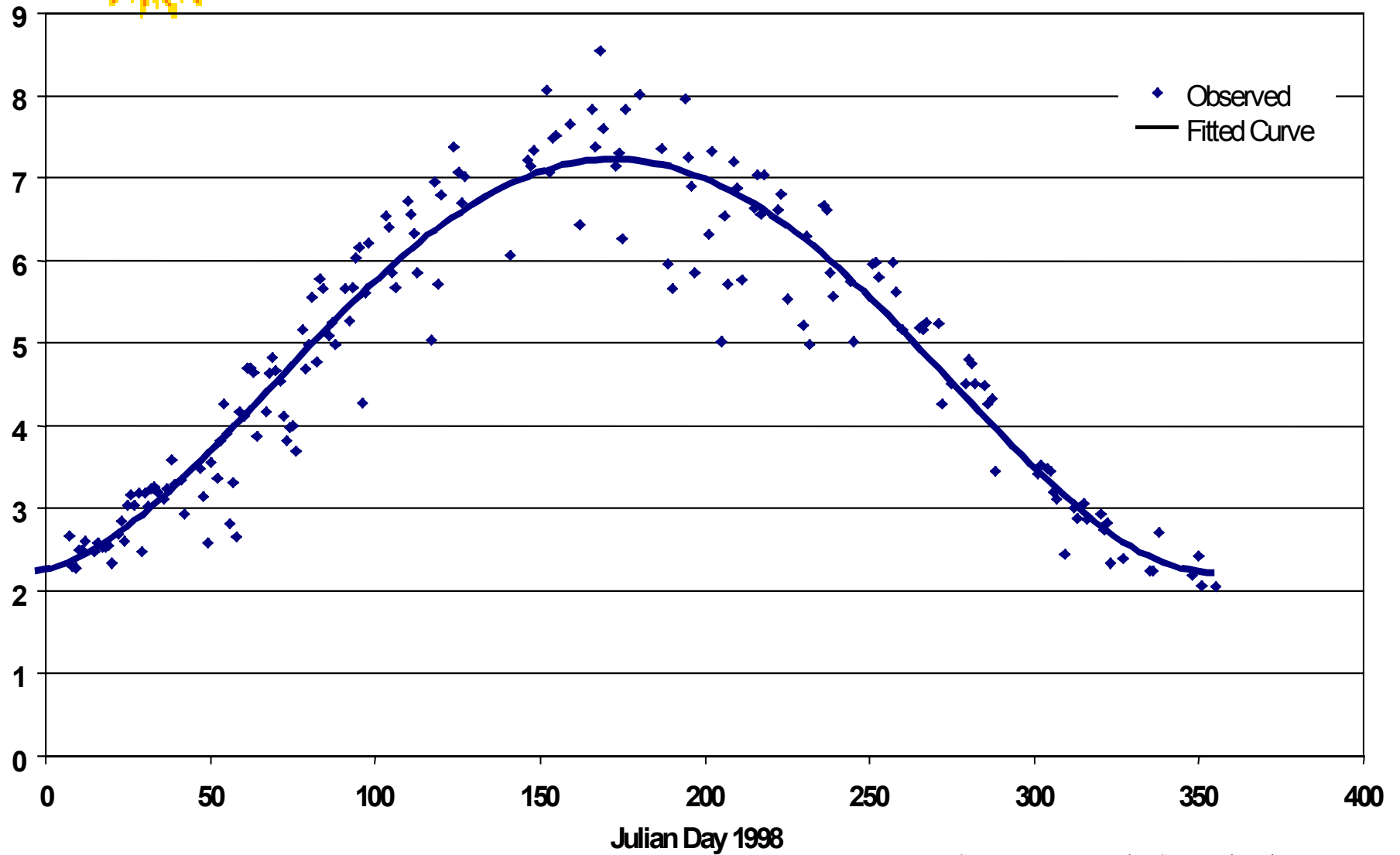
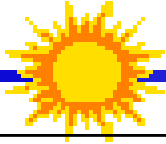
Solar Still Operation



Natural Evaporation process to produce high quality potable water



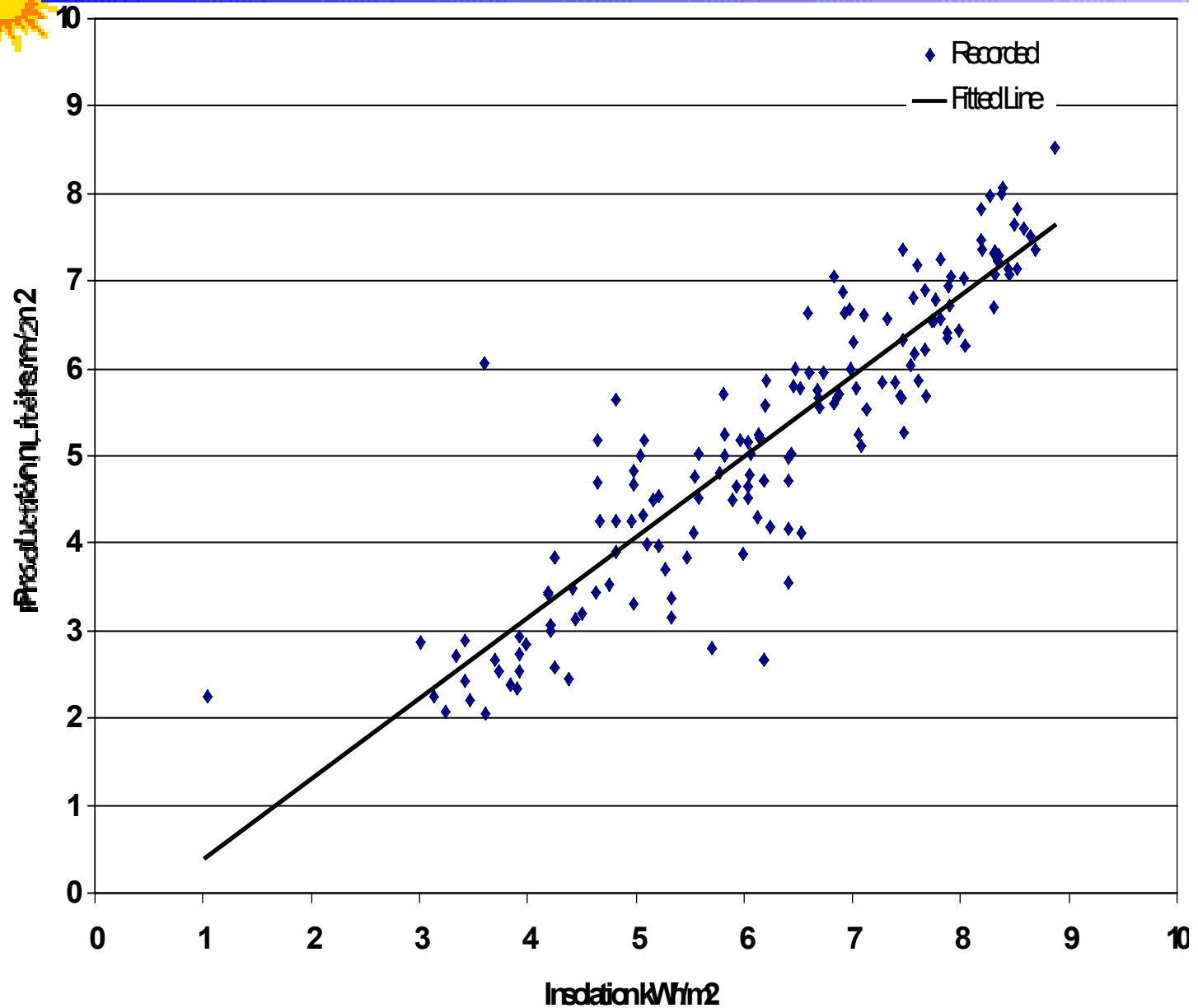
Annual Solar Still Production Las Cruces, New Mexico



Courtesy: New Mexico State University



Water Production Compared to Solar Insolation





Water Quality Results

Sandia National Laboratories

SampleType	13‰salinity feedwater	SolarDistilled water(13‰case)	16‰salinity feedwater	SolarDistilled water(16‰case)
Calcium(total)	340	1.5	371	<0.10
Iron(total)	0.27	<0.05	0.48	<0.06
Magnesium(total)	2.1	2.1	<0.005	<0.005
Manganese(total)	0.04	<0.02	0.07	<0.02
AmmoniasN	<0.1	0.1	<0.1	<0.1
Chloride	19000	<1.0	25000	2.6
FixedSolids	32000	<1.0	41000	31
NitrateasNO ₃	34	0.1	26	<0.1
NitrateasNO ₂	0.013	<0.01	0.02	<0.01
TDS	36000	<1.0	48000	<1.0
Volatiles & Organic	4200	<1.0	6000	13



Water Quality Test Results

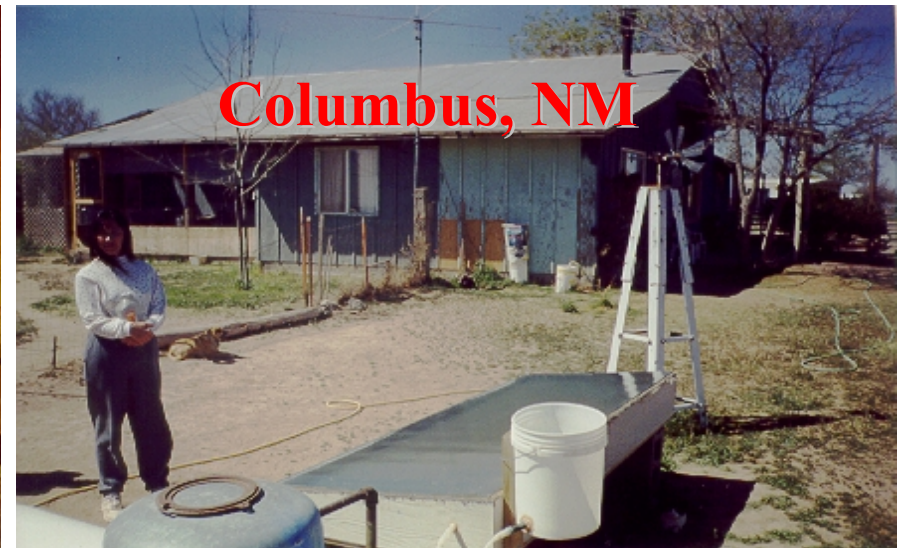
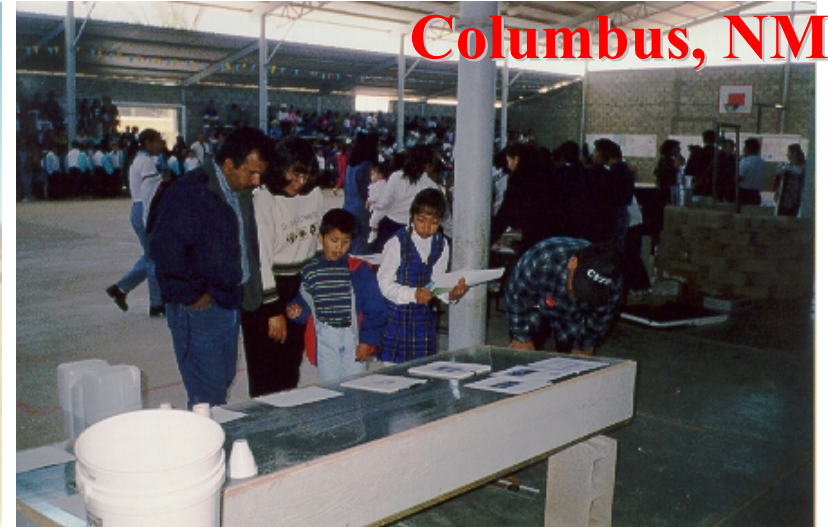
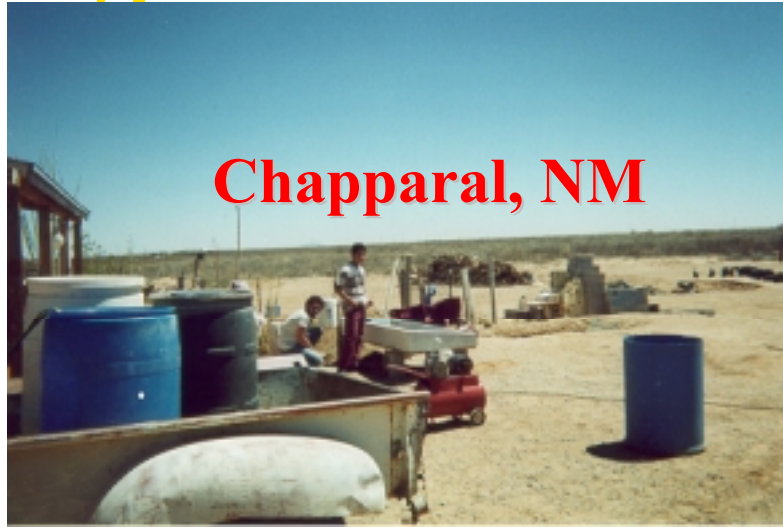
New Mexico State University

Field # Ref. No.	Conductivity, µS/cm	Hardness mg/L as CaCO ₃	Fluoride mg/L	pH
# 2 Input	1190	260	6.2	7.9
# 2 Output	4.8	4	0.1	9.2
# 2 Input	1180	250	8.2	7.4
# 2 Output	1.8	0	0.10	9.1
# 2 Input	1200	250	6.0	8.1
# 2 Output	5.8	8	0	8.8
# 3 Input	2390	480	n/a	6.8
# 3 Output	4	4	n/a	9.4

Sample	Volume Tested ml	Total Organisms per liter
Supply Distillate	50 1,000	16,000 4 (No <i>E. coli</i>)
<i>E. coli</i> Seed Distillate	-- 750	2,900,000,000 11 (No <i>E. coli</i>)
<i>E. coli</i> Seed Distillate	-- 1,000	7,500,000,000 18 (No <i>E. coli</i>)
Supply Distillate	10 1,000	24,000 13 (No <i>E. coli</i>)
Supply Distillate	1 1,000	12,000 6 (No <i>E. coli</i>)



U.S. Applications in the Southwest



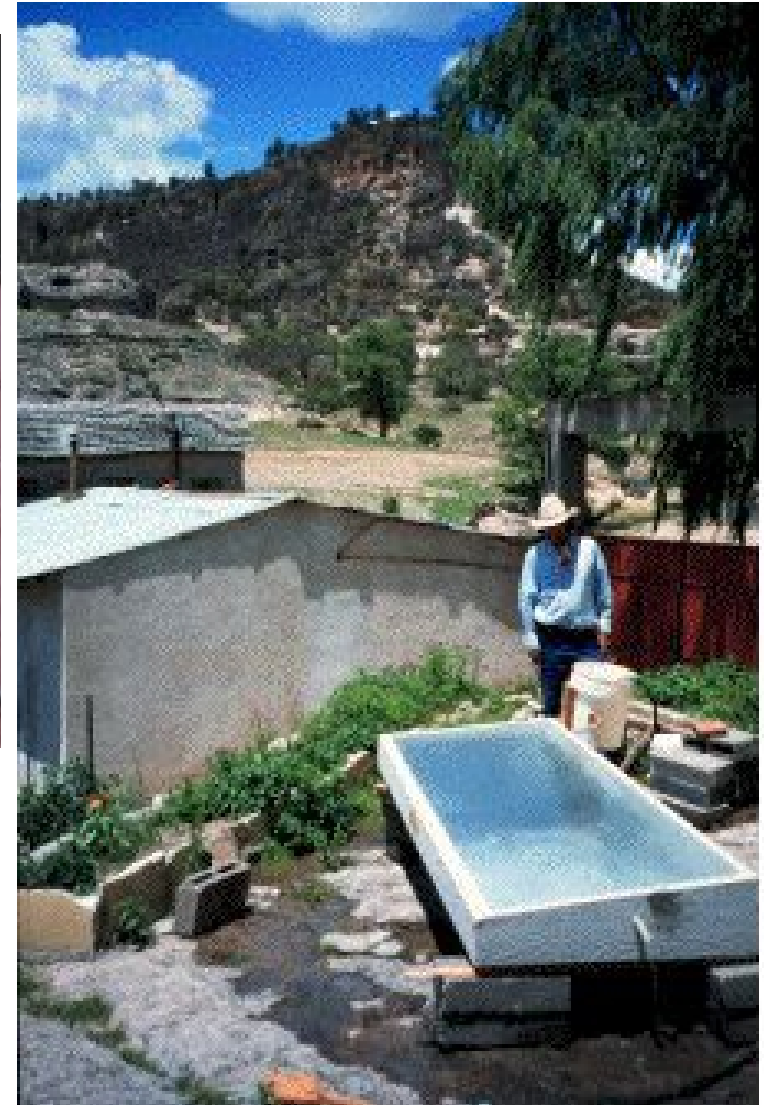


Applications in Chihuahua, Mexico



Cd. Juárez Orphanage

**Tarahumara Indian Rural
Health Clinic, Norogachi**





Anapra Colonia, Cd. Juárez, Mexico



The Valdez family used to buy water at 13 pesos every 3 days (~US\$175/year).

They believe that the still water tastes better than store-bought water and now they have more water. Simple still payback is 3.7 years for them.

Technology Cost Comparison: Amortization 7% for 10 years



Method(\$ Ê	Initial Cost per month (\$)	Initial Cost per gallon (\$)	Replacement Parts per gallon (\$)	Power Cost per gallon (\$)	Total Cost Per gallon (\$)
R.O. 4 stgs .	9. 2	0. 23	0. 10		0. 2
R.O. 4 stgs .	8. 7	0. 16	0. 86		0. 2
R.O. 3 stgs .	6. 3	0. 90	0. 94		0. 8
Dist -E dec.	5. 6	0. 06	0	0. 3	0. 4
Dist -E ect .	16 22	0. 26	0	0. 3	0. 5
Dist -E ect .	20 89	0. 29	0	0. 3	0. 6
Solar sti I (1.7 m ²)	8. 2	0. 10	0		0. 1
Solar sti I (many)	5. 4	0. 04	0		0. 0
Bott led Water	0. 0	0. 00	0	0	0. 2

Clean Water Technology Effectiveness Comparison



Pollutant	Purification		Crossover		Disinfection				
	Carbon Filter	Deionization	RO	Distillation	Boiling	Chlorination	UV*	Ozonation	Mixed Ox
Arsenic									
Bacteria									
Cadmium									
Calcium									
Chlorides									
Chlorine			*	*					
Crypto									
Detergents									
Fluoride									
Iron									
Lead									
Mercury									
Nitrate									
Organics			*	*					
Pesticides			*	*					
Sediement									
Sodium/Salt									
Viruses									
Residual									

	Ineffective or no reduction
	Significant reduction
	Complete reduction

* carbon filtered required